UNIT 5 PROBLEM-BASED LEARNING

Fossilized

EVIDENCE OF LIFE LONG AGO

Imagine you wanted to know about life in your town one hundred years ago. You could read newspapers or look at photographs from that time. Or you could talk to people who know stories from that time. But what if you want to know what the place you live in was like millions of years ago? Earth's first living things arose over 3 billion years ago. Ever since, new species have evolved, and most of them have also gone extinct. We know they existed because a few organisms left behind fossils, which are preserved traces or remains. Fossils provide evidence for the history of life on Earth, as well as explanations for how life has changed over time.

PROBLEM LAUNCH
Conduct research on a fossil found in your region. Gather information to create a natural history display of your fossil.

VIDEO

BOUNCE TO ACTIVATE

Watch a video about how fossils are discovered and the information that can be gathered from fossils.

PROBLEM: What can a fossil tell you about life long ago?

TO SOLVE THIS PROBLEM, perform these activities as they come up in the unit, and record your findings in your Explorer's Journal.

INTERACTIVITY

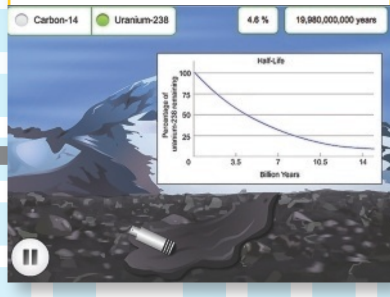
Learn how fossils provide evidence of evolution.

AUTHENTIC READING

Read an article about how *Tiktaalik* fossils have provided scientists with evidence of how aquatic life evolved for life on land.

INTERACTIVITY

Estimate the age of fossils at a dig site using radiometric dating.



STEM PROJECT

Create a model of your fossil as well as a short write-up of your research.

PROBLEM WRAP-UP

Present your fossil as part of a class natural history exhibit. Present your model as well as other information to help others learn about your fossil.

CHAPTER 19

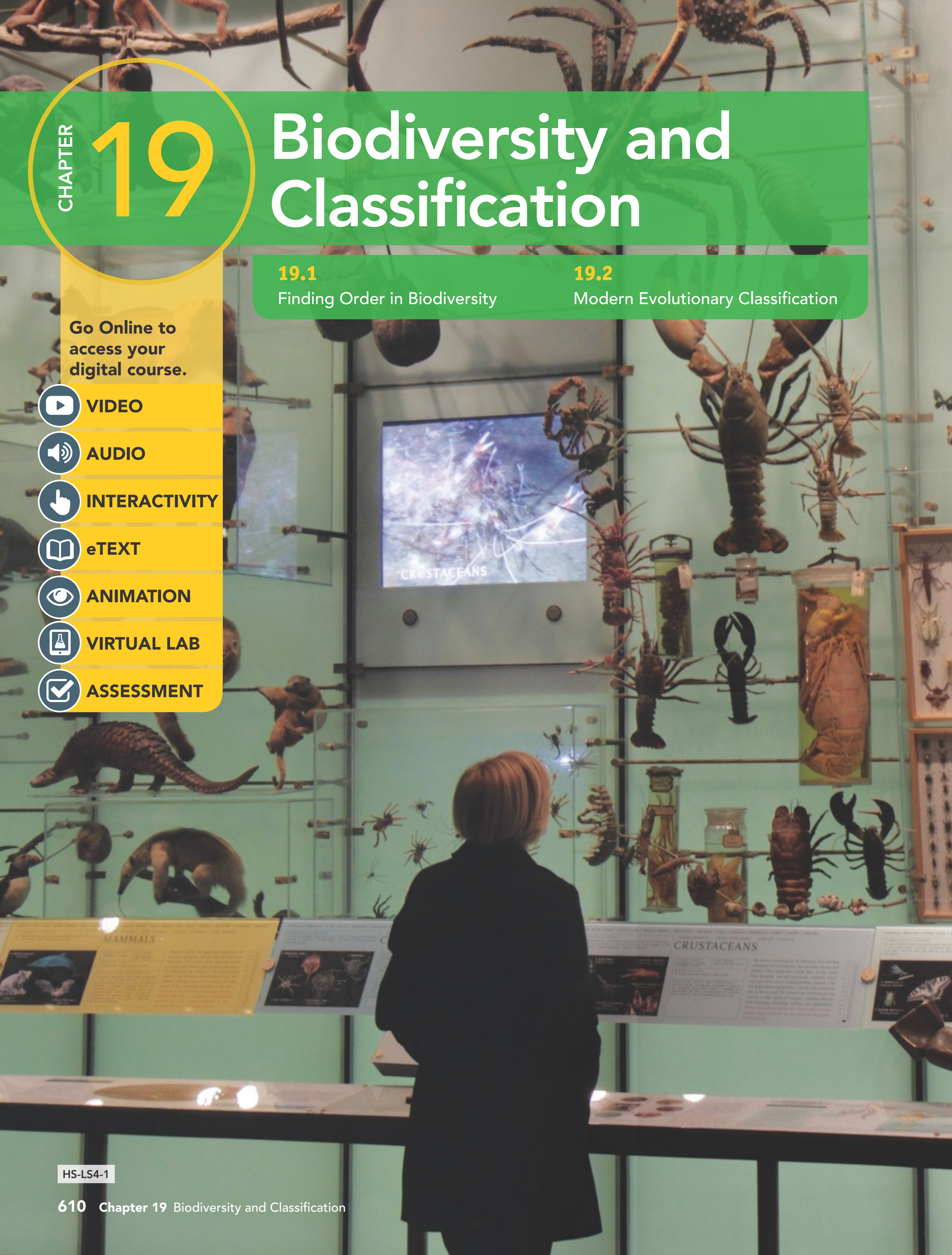
Biodiversity and Classification

19.1 Finding Order in Biodiversity

19.2 Modern Evolutionary Classification

Go Online to access your digital course.

- VIDEO
- AUDIO
- INTERACTIVITY
- eTEXT
- ANIMATION
- VIRTUAL LAB
- ASSESSMENT



HS-LS4-1

CASE STUDY

It's a duck! No, it's a beaver! No, it's a platypus!

The first European scientist to see a specimen labeled it a hoax—although he did give it a scientific name. An anatomist called it an "amphibious creature of the mole kind." It had webbed feet with claws, an otter's body, a beaver's tail, and a duck's beak. Males carried spurs that delivered snake-like venom. Was it fake? Or was it real?

Australia's native people have known about the curious creature we call a platypus for a very long time. One of their myths suggests that a particularly determined water rat somehow managed to mate with a female duck. The offspring combine their father's four legs and fur, with their mother's beak and webbed feet. (Not likely in the real world.)

When a scientist at the British Museum first saw a dried specimen, he doubted "the genuine nature of the animal." In fact, he cut around the beak, trying to show that someone had sewn a bird's beak onto a mammal skin. (He failed.)

Only after many specimens showed up in museums, and lots more reports of live platypus came in from Australia, did Europeans finally admit that the creatures were real. They then tried to figure out where this oddball animal belonged in the scheme of life they were constructing. (They got very confused.)

A platypus is about the size of a beaver, with a furry body and a broad tail. It lives in rivers, lakes, and streams. Females produce and feed their young milk. And males' reproductive organs resemble those of mammals.

So … are they mammals? Maybe. But females' reproductive organs share a mix of reptilian and mammalian traits. They lay eggs with leathery shells. Males' venom resembles that of snakes and other reptiles. And their four limbs point outward from the sides of their bodies like those of alligators and crocodiles.

So … are they reptiles? Perhaps. But the platypus also has features more often seen in birds, such as a beak that looks remarkably like the ones ducks use to dig through the muck of rivers and streams. Females incubate eggs for about 10 days.

Eventually, biologists decided—correctly—that these strange creatures were very odd mammals. They are further placed into an ancient group of egg-laying mammals called monotremes, whose ancestors split off from ancestors of other mammals back during the days of the dinosaurs. Why mammals? Hair or fur and the production of milk for young are characteristics that distinguish all mammals from all other animal groups. Recent studies of the platypus genome confirm that they carry some genes similar to those of birds, some similar to genes of reptiles, and some like those of other mammals.

What can the platypus teach us about the evolution of mammals? Why are monotremes classified as mammals?

Throughout this chapter, look for connections to the CASE STUDY to help you answer these questions.

LESSON 19.1

Finding Order in Biodiversity

Puma concolor

KEY QUESTIONS

- *What are the goals of binomial nomenclature and taxonomy?*
- *How did Linnaeus group species into larger taxa?*
- *What are the six kingdoms of life as they are now identified?*

VOCABULARY

taxonomy
binomial nomenclature
genus
taxon
family
order
class
phylum
kingdom

READING TOOL

In your **Biology Foundations Workbook**, order the events listed to describe the history of how scientists have organized and labeled living organisms.

As European scientists traveled the world, they discovered plants and animals they had never seen before. They were eager to communicate with each other about their discoveries. But the common names for organisms back then varied a lot from place to place. In fact, common names can still be confusing today. For example, in the United States, this big cat may be known as a cougar, a mountain lion, or a puma. Some of its Spanish common names are león Americano, león bayo, león Colorado, and onza bermeja! So, it isn't surprising that biologists need a scientific system to universally identify species.

Assigning Scientific Names

Biologists now identify and organize biodiversity through a standardized system. **Taxonomy** is a system of naming and classifying organisms based on shared characteristics and universal rules. Each scientific name must refer to one and only one species. Scientists must all agree to use the same name for that species.

At first, European scientists tried to assign Latin or Greek names to each species. Unhappily, that idea didn't work well. Early scientific names often described species in great detail, so names could be ridiculously long. For example, the English translation of the scientific name of a tree might be "Oak with deeply divided leaves that have no hairs on their undersides and no teeth around their edges." It was also difficult to standardize these names.

Binomial Nomenclature

In the 1730s, Swedish botanist Carolus Linnaeus developed a naming system called **binomial nomenclature**. The system proved very successful and popular, and is still in use today. ***In binomial nomenclature, each species is assigned a two-part scientific name.*** Scientific names are written in italics. The first word begins with a capital letter, and the second word is in lowercase.

For example, the scientific name of the polar bear shown in **Figure 19-1** is *Ursus maritimus*. The first part of that name—*Ursus*—is the genus to which the species belongs. A **genus** (plural: genera, JEN ur uh) is a group of similar species. The genus *Ursus* contains five other species of bears, such as *Ursus arctos*, the brown bear or grizzly bear, and *Ursus americanus*, the American black bear. The second part of a scientific name is often a description of an important trait or the organism's habitat. The Latin word *maritimus* refers to the sea, because polar bears often live on pack ice that floats in the sea.

VIDEO

Discover what it is like to find a new species.

Classifying Species into Larger Groups In addition to naming organisms, biologists classify living and fossil species into larger groups. Whether you realize it or not, you classify things all the time. You may, for example, talk about "teachers" or "mechanics." Sometimes you refer to a more specific group, such as "biology teachers" or "auto mechanics." When you do this, you refer to these groups using widely accepted names and characteristics that many people understand.

The science of naming and grouping organisms is called **systematics** (sis tuh MAT iks). ***The goal of systematics is to organize living things into groups that have biological meaning.*** Biologists often refer to these groups as **taxa** (singular: taxon).

READING CHECK **Synthesize** What are the parts of a scientific name for an organism?

Figure 19-1

Binomial Nomenclature

Different species within the same genus, such as these bears, lemurs, and oak trees, share many characteristics in common, but differ from each other in distinctive ways.

The Linnaean Classification System

Linnaeus developed a classification system that organized species into taxa based on similarities and differences he could see. ***Over time, Linnaeus's original classification system expanded to include seven hierarchical taxa: species, genus, family, order, class, phylum, and kingdom.***

INTERACTIVITY

Explore classification using the Linnaean system.

Species and Genus

Let's explore this classification system using camels as our subject. The scientific name of a camel with two humps is *Camelus bactrianus*. The second part of the name refers to Bactria, an ancient country in Asia. As you can see in **Figure 19-2**, the genus *Camelus* also includes another species, *Camelus dromedarius*, the dromedary, which has only one hump.

Family

Bactrian camels and dromedaries resemble llamas, which live in South America. But llamas are more similar to other South American species than they are to Asian and African camels. Therefore, llamas are placed in a different genus, *Lama*, and their species name is *Lama glama*. The genera *Camelus* and *Lama* are grouped with other genera that share many similarities into a larger taxon, the **family** Camelidae.

Order

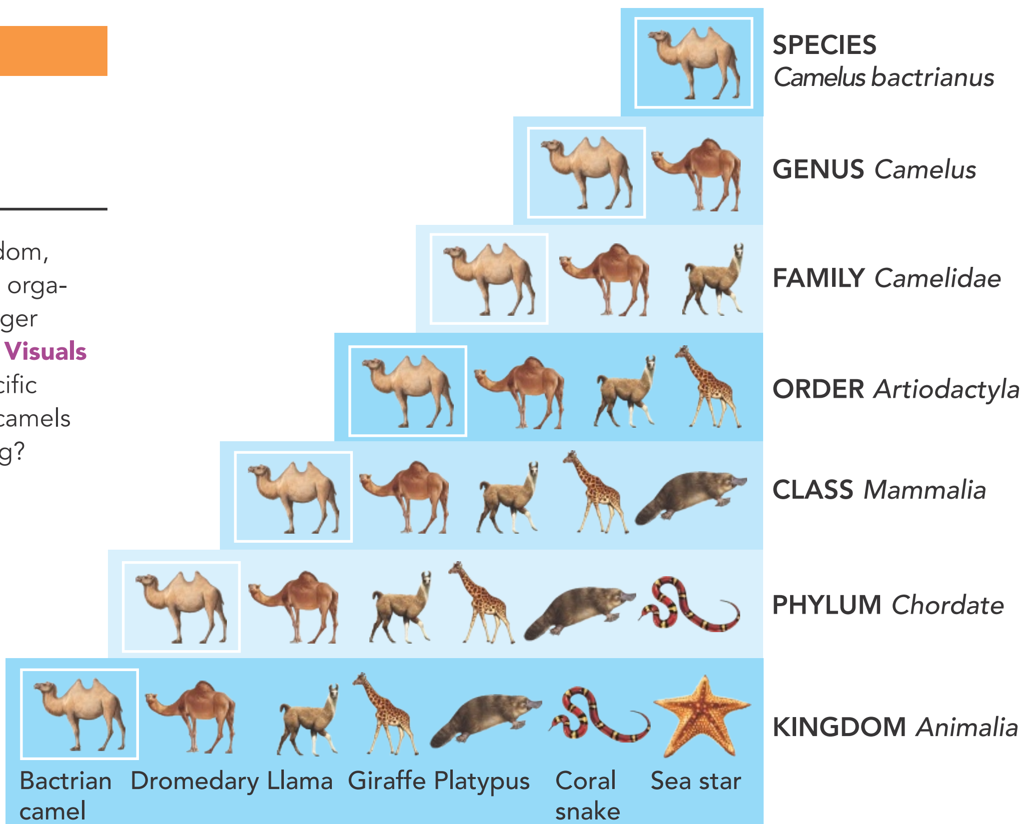
Closely related families are grouped into the next larger taxon, called an **order**. Camels and llamas (family Camelidae) are grouped with several other animal families, including deer (family Cervidae) and cattle (family Bovidae). They form the order Artiodactyla, which includes hoofed animals with an even number of toes.

CASE STUDY

Figure 19-2

From Species to Kingdom

From species to kingdom, *Camelus bactrianus* is organized in larger and larger groups. **Interpret Visuals** What is the most specific group to which both camels and platypuses belong?



Class Similar orders, in turn, are grouped into the next larger rank, a **class**. The order Artiodactyla is placed in the class Mammalia. The mammals include all animals that are warmblooded, have body hair, and produce milk for their young.

Phylum Classes are grouped into a **phylum**. A phylum includes organisms that can look different, but share important characteristics. The class Mammalia is placed in the phylum Chordata. The chordates are animals that share a body feature called a nerve cord along the back and other important body features. Phylum Chordata includes mammals, birds (class Aves), reptiles (class Reptilia), amphibians (class Amphibia), and all classes of fishes.

Kingdom The largest and most inclusive of traditional taxonomic categories is the **kingdom**. All multicellular animals are placed in the kingdom Animalia.

Classification Changes with New Discoveries In a sense, organisms determine on their own who belongs to their species. How? By deciding with whom they mate! If individuals living under natural conditions mate and produce fertile offspring, those parents and offspring are members of the same species. That's a simple "natural" way to define species, the smallest important taxon.

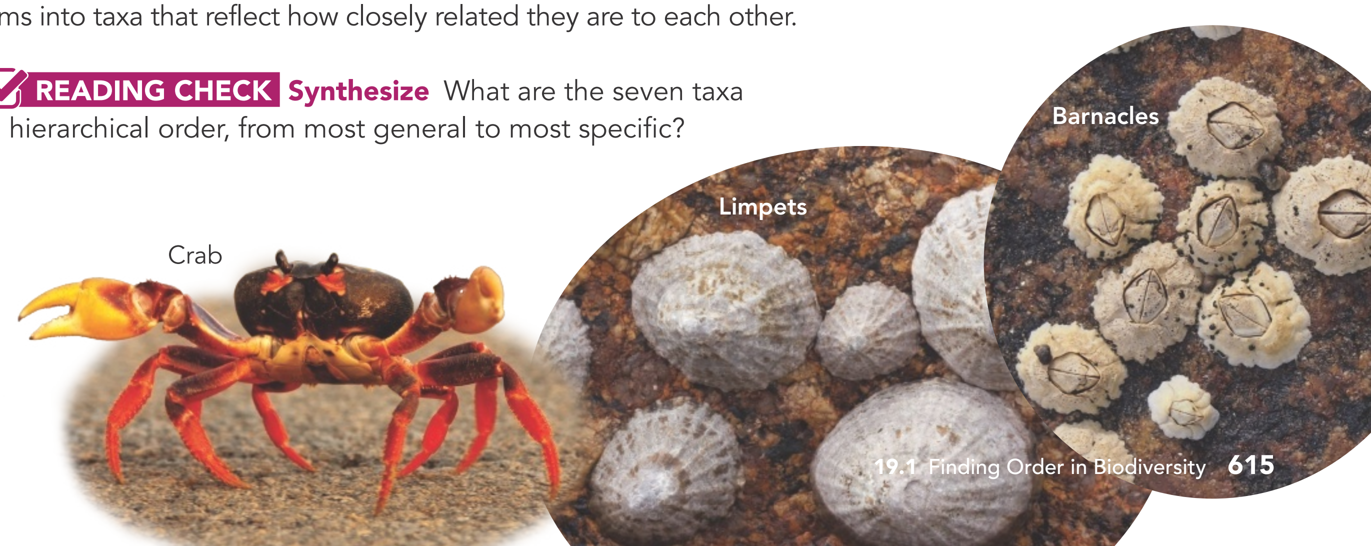
Higher taxa, on the other hand, are defined by rules created by researchers like Linnaeus. He classified organisms according to rules based on similarities and differences he could see. But that can get tricky. Look at the animals in **Figure 19-3**. Adult barnacles and limpets both live attached to rocks, and have similar-looking shells. Adult crabs, on the other hand, scramble around on jointed legs. Based on these easily visible characteristics, would you classify limpets and barnacles together, and put crabs in a different group?

As biologists attempted to classify more and more organisms, these kinds of questions arose frequently. Which characteristics are most important? In addition, ongoing discoveries in genetics, cell biology, and development revealed scores of new and different characteristics. Rules for ranking the importance of those characteristics in forming higher taxa groups have changed over time. In addition, biologists today want classification to reflect Darwinian theory by grouping organisms into taxa that reflect how closely related they are to each other.

READING CHECK **Synthesize** What are the seven taxa in hierarchical order, from most general to most specific?

BUILD VOCABULARY

Multiple Meanings The words *family, order, class,* and *kingdom* all mean something different in everyday usage than they do in biological classification. For example, in everyday usage, a *family* is a group of people who are related to one another. In systematics, a *family* is a group of genera. Use a dictionary to find the common meanings of *order, class,* and *kingdom.*



INTERACTIVITY

Figure 19-3

Classifying Organisms by Appearance

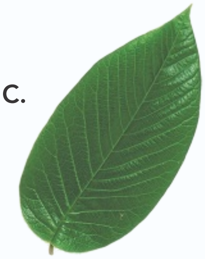
Barnacles may appear similar to limpets, but their interiors show more structural similiarity to crabs. These animals show the difficulty of classifying organisms by appearances alone.

Quick Lab | Guided Inquiry

Using a Dichotomous Key

A. 

B. 

C. 

A dichotomous key is a series of steps that lead to a classification of an organism. It consists of a series of paired statements that describe alternative characteristics of organisms. Use the key to identify the type of tree that produced each leaf. Begin with Step 1. Your answer to each step will either bring you to the next step or identify the tree. The results will show either the next step or the name of the tree.

ANALYZE AND CONCLUDE

1. **Classify** Identify the type of tree that produced leaves A, B, and C.
2. **Identify Patterns** Use the objects provided by your teacher to make your own dichotomous key.

Dichotomous Key for Classifying Leaves

Step	Leaf Characteristics	Result
1a 1b	Compound leaf, divided into leaflets Simple leaf, not divided into leaflets	Go to step 2 Go to step 4
2a 2b	Leaflets all attached at a central point Leaflets attached at several points	Buckeye Go to step 3
3a 3b	Leaflets tapered with pointed tips Leaflets oval with rounded tips	Pecan Locust
4a 4b	Veins branched out from one central point Veins branched off main vein in middle of the leaf	Go to step 5 Go to step 6
5a 5b	Heart-shaped leaf Star-shaped leaf	Redbud Sweet gum
6a 6b	Leaf with jagged edges Oval leaf	Birch Magnolia

Changing Ideas About Kingdoms

During Linnaeus's time, the only known fundamental differences among living things were the characteristics that separated animals from plants. For this reason, the two kingdoms of this time were Animalia and Plantae. Over time, biologists learned more about the natural world. The classification systems have changed dramatically, as shown in **Figure 19-4**.

From Two to Six Kingdoms Researchers found faults with the two-kingdom system when they began to study microorganisms. They discovered that single-celled organisms were significantly different from plants and animals. At first, they placed all microorganisms in a single kingdom, called Protista. Then yeasts, molds, and multicellular mushrooms were placed in the new kingdom Fungi.

Later still, scientists realized that bacteria lack the nuclei, mitochondria, and chloroplasts found in other forms of life. All prokaryotes were placed in another new kingdom, called Monera. Single-celled eukaryotic organisms remained in the kingdom Protista. This process produced five kingdoms: Monera, Protista, Fungi, Plantae, and Animalia.

By the 1990s, researchers had learned enough about bacteria to realize that some organisms lumped together as Monera were very different from one another genetically and biochemically. As a result, monerans were separated into two kingdoms, Eubacteria and Archaebacteria. The total number of kingdoms is now six. ***The six-kingdom system of classification includes the kingdoms Eubacteria, Archaebacteria, Protista, Fungi, Plantae, and Animalia.*** This system of classification is shown in the bottom row of the chart in **Figure 19-4**.

Visual Summary

Figure 19-4

Kingdoms Over Time

This diagram shows some of the ways in which organisms have been classified into kingdoms since the 1700s.

<table>
<tr><th colspan="7">Kingdoms of Life, 1700s–1990s</th></tr>
<tr><th>First Introduced</th><th colspan="6">Names of Kingdoms</th></tr>
<tr><td>1700s</td><td colspan="5">Plantae</td><td>Animalia</td></tr>
<tr><td>Late 1800s</td><td colspan="3">Protista</td><td colspan="2">Plantae</td><td>Animalia</td></tr>
<tr><td>1950s</td><td colspan="2">Monera</td><td>"Protista"</td><td>Fungi</td><td>Plantae</td><td>Animalia</td></tr>
<tr><td>1990s</td><td>Eubacteria</td><td>Archaebacteria</td><td>"Protista"</td><td>Fungi</td><td>Plantae</td><td>Animalia</td></tr>
</table>

Eubacteria

Lactobacillus acidophilus

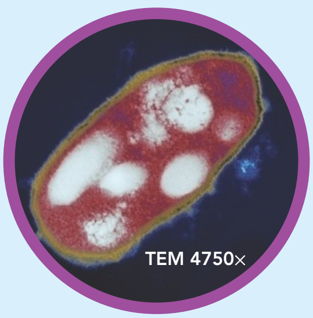
"Protista"

Euglena viridis

Plantae

Paeonia lactiflora

Archaebacteria



Halobacterium mediterranei

Fungi

Amanita muscaria

Animalia

Symphorichthys spilurus

Classification of Living Things						
DOMAIN	Bacteria	Archaea	Eukarya			
KINGDOM	Eubacteria	Archaebacteria	"Protista"	Fungi	Plantae	Animalia
CELL TYPE	Prokaryote	Prokaryote	Eukaryote	Eukaryote	Eukaryote	Eukaryote
CELL STRUCTURES	Cell walls with peptidoglycan	Cell walls without peptidoglycan	Cell walls of cellulose in some; some have chloroplasts	Cell walls of chitin	Cell walls of cellulose; chloroplasts	No cell walls or chloroplasts
NUMBER OF CELLS	Unicellular	Unicellular	Most unicellular; some colonial; some multicellular	Most multicellular; some unicellular	Most multicellular; some green algae unicellular	Multicellular
MODE OF NUTRITION	Autotroph or heterotroph	Autotroph or heterotroph	Autotroph or heterotroph	Heterotroph	Autotroph	Heterotroph
EXAMPLES	*Streptococcus, Escherichia coli*	Methanogens, halophiles	*Amoeba, Paramecium,* slime molds, giant kelp	Mushrooms, yeasts	Mosses, ferns, flowering plants	Sponges, worms, insects, fishes, mammals

Figure 19-5

Three Domains

Today, organisms are commonly grouped into three domains and six kingdoms. This table summarizes the key characteristics used to classify organisms into these higher taxa.

Three Domains Still more recent genomic analysis has revealed that the two main prokaryotic groups are even more different from each other, and from eukaryotes, than previously thought. So biologists established a new taxonomic category—the domain. A **domain** is even larger than a kingdom. The three are Bacteria (the old kingdom Eubacteria), Archaea (the old kingdom Archaebacteria), and Eukarya (kingdoms Fungi, Plantae, Animalia, and "Protista"), as shown in **Figure 19-5**.

Why do we put quotation marks around the old kingdom Protista? Recent research shows that there is no way to put all unicellular eukaryotes into a taxon that contains a single common ancestor, all of its descendants, and only those descendants. Since only that kind of taxon is valid under evolutionary classification, quotation marks are used to show that this is not a taxon of the sort modern biologists prefer.

LESSON 19.1 Review

KEY QUESTIONS

1. Identify two goals of systematics.
2. In which group of organisms are the members more closely related—all of the organisms in the same kingdom or all of the organisms in the same order? Explain your answer.
3. How do the six kingdoms fit into the three domains?

CRITICAL THINKING

4. **Define the Problem** What problem is solved by the Linnaean system of classification?
5. **Identify Patterns** A starfish and a sea cucumber are both members of the same phylum, called Echinodermata. From this information, what other taxa can you conclude that they share?
6. **CASE STUDY** The platypus is the only living member of the family Ornithorhynchidae. Based on this information, what conclusion can you make about its genus?

Modern Evolutionary Classification

LESSON 19.2

KEY QUESTIONS
- *What is the goal of evolutionary classification?*
- *What is a cladogram?*
- *How are DNA sequences used in classification?*
- *What does the tree of life show?*

HS-LS4-1: Communicate scientific information that common ancestry and biological evolution are supported by multiple lines of empirical evidence.

VOCABULARY
phylogeny
clade
cladogram
derived character

READING TOOL
As you read, define and give examples of derived characters and lost traits. Fill in the table in your **Biology Foundations Workbook.**

Darwin's "tree of life" suggests a way to classify organisms based on how closely related they are. When taxa are rearranged this way, some old Linnaean ranks fall apart. For example, the Linnaean class Reptilia isn't valid unless birds are included—which means birds are reptiles! And not only are birds reptiles, they are also descended from dinosaurs! Wondering why? To understand, we need to look at the way evolutionary classification works.

Evolutionary Classification

The core Darwinian concept of descent with modification revolutionized classification. First, Darwinian theory gave birth to the field of phylogeny. **Phylogeny** (fy LAHJ uh nee) is the study of the evolutionary history of lineages of organisms. Advances in phylogeny, in turn, led to evolutionary classification. ***The goal of evolutionary classification is to group species into larger categories that reflect lines of evolutionary descent, rather than overall similarities and differences.***

Evolutionary classification places organisms into higher taxa whose members are more closely related to one another than they are to members of any other group. The larger a taxon is, the farther back in time all of its members shared a common ancestor. This is true all the way up to the largest taxa—the domains described in the last lesson.

Classifying organisms according to these rules places them into groups called clades. A **clade** is a group of species that includes a single common ancestor and all descendants of that ancestor—living and extinct. Some of the old higher taxa fit those requirements well. Other old taxa are not proper clades. Certain taxa fail the "clade test" because they include species descended from more than one different ancestor. Others (like the Linnaean class Reptilia) are not valid because they exclude some descendants of a single common ancestor (like birds).

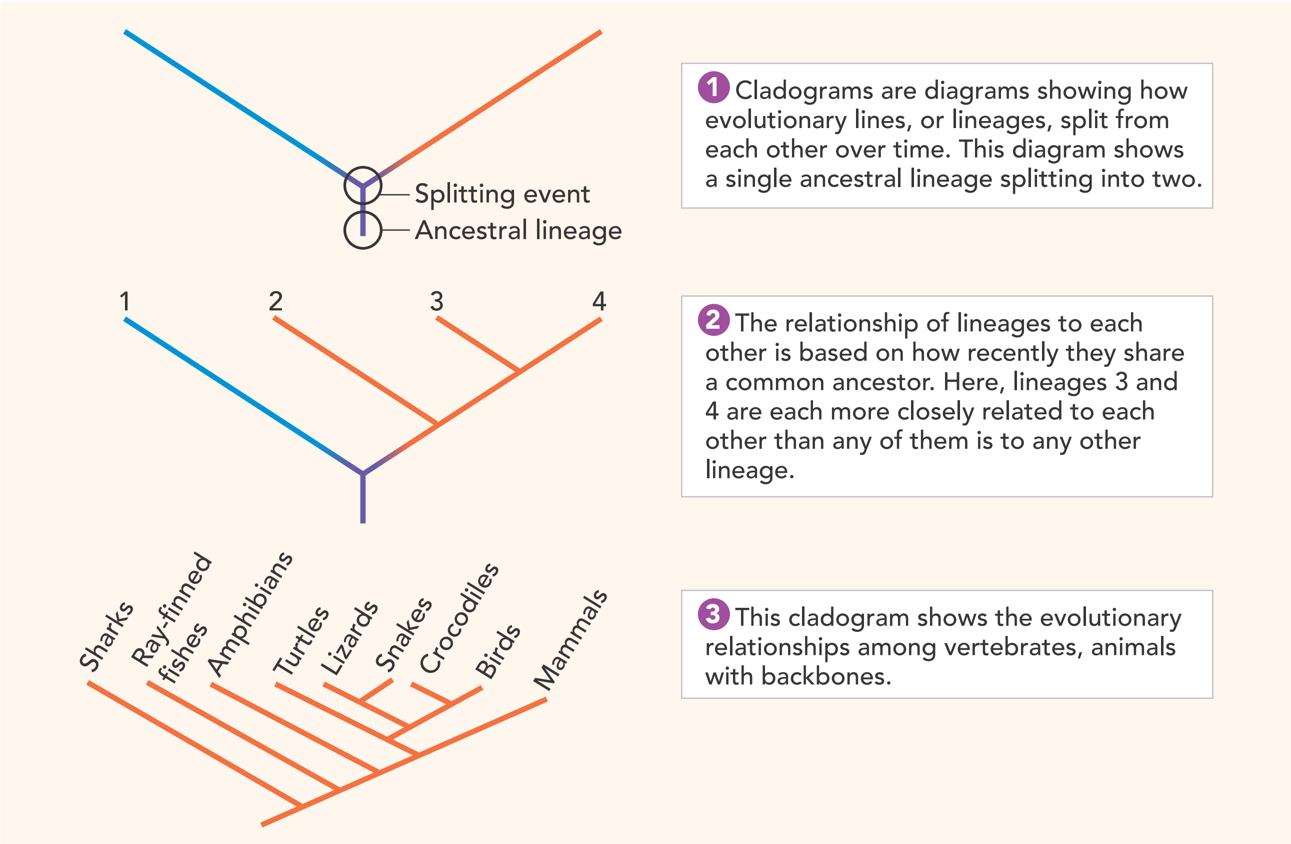


Figure 19-6

Building a Cladogram

A cladogram shows relative degrees of relatedness among lineages.

Cladograms

Modern evolutionary classification uses a method called cladistic analysis. Cladistic analysis compares carefully selected traits to determine the order in which groups of organisms branched off from their common ancestors. This information is then used to link clades together into a diagram called a **cladogram**. ***A cladogram links groups of organisms by showing current hypotheses about how evolutionary lines, or lineages, branched off from common ancestors.***

Building Cladograms To understand how cladograms are constructed, think back to the process of speciation and look at part 1 of **Figure 19-6**. Part 1 represents how one ancestral species branches into two species, each of which could found a new lineage. Now look at part 2. The bottom, or "root" of this cladogram, represents the common ancestor shared by all organisms in the cladogram. The branching pattern shows how closely related various lineages are. Each branch point represents the last point at which species in lineages above that point shared a common ancestor. Lineages 3 and 4 share a common ancestor more recently with each other than they do with lineage 2. So you know that lineages 3 and 4 are more closely related to each other than either is to lineage 2. The same is true for lineages 2, 3, and 4. All three of these groups are more closely related to each other than any of them is to lineage 1. Now look at part 3 of the figure. Does it surprise you that amphibians are more closely related to mammals than they are to ray-finned fish?

INTERACTIVITY

Complete a cladogram that shows the evolutionary history of plants.

Derived Characters

Derived Characters Cladistic analysis focuses on certain kinds of characters, called derived characters. A **derived character** is a trait that arose in the most recent common ancestor of a lineage and was passed to its descendants.

Whether or not a character is derived depends on the level at which you're grouping organisms. Here's what we mean. **Figure 19-7** shows several traits shared by coyotes and lions, members of the clades Tetrapoda, Mammalia, and Carnivora. Four limbs is a derived character for the entire clade Tetrapoda, because the common ancestor of all tetrapods had four limbs. But if we look just at mammals, four limbs is *not* a derived character. If it were, *only* mammals would have four limbs. Hair, on the other hand, is a derived character for the clade Mammalia. But neither four limbs nor hair is a derived character for clade Carnivora. Why? Other species not in this clade also have four limbs (i.e. frogs) or hair (i.e. rodents). Specialized shearing teeth, however, is a derived character for Carnivora. What about retractable claws? This trait is found in lions, but not in coyotes. Thus, retractable claws is a derived character for the clade Felidae, a subgroup of Carnivora that consists of cats.

Losing Traits As stated, four limbs is a derived character for clade Tetrapoda. But what about snakes? Snakes are reptiles, which are tetrapods. But snakes don't have four limbs! The *ancestors* of snakes, however, did have four limbs. Somewhere in the lineage leading to modern snakes, that trait was lost. Because distantly related groups can sometimes lose a character, systematists are cautious about using the *absence* of a trait as a character in their analyses. After all, whales don't have four limbs either, but snakes are certainly more closely related to other reptiles than they are to whales.

READING CHECK **Classify** Are both coyotes and lions a member of the clade Carnivora? Explain.

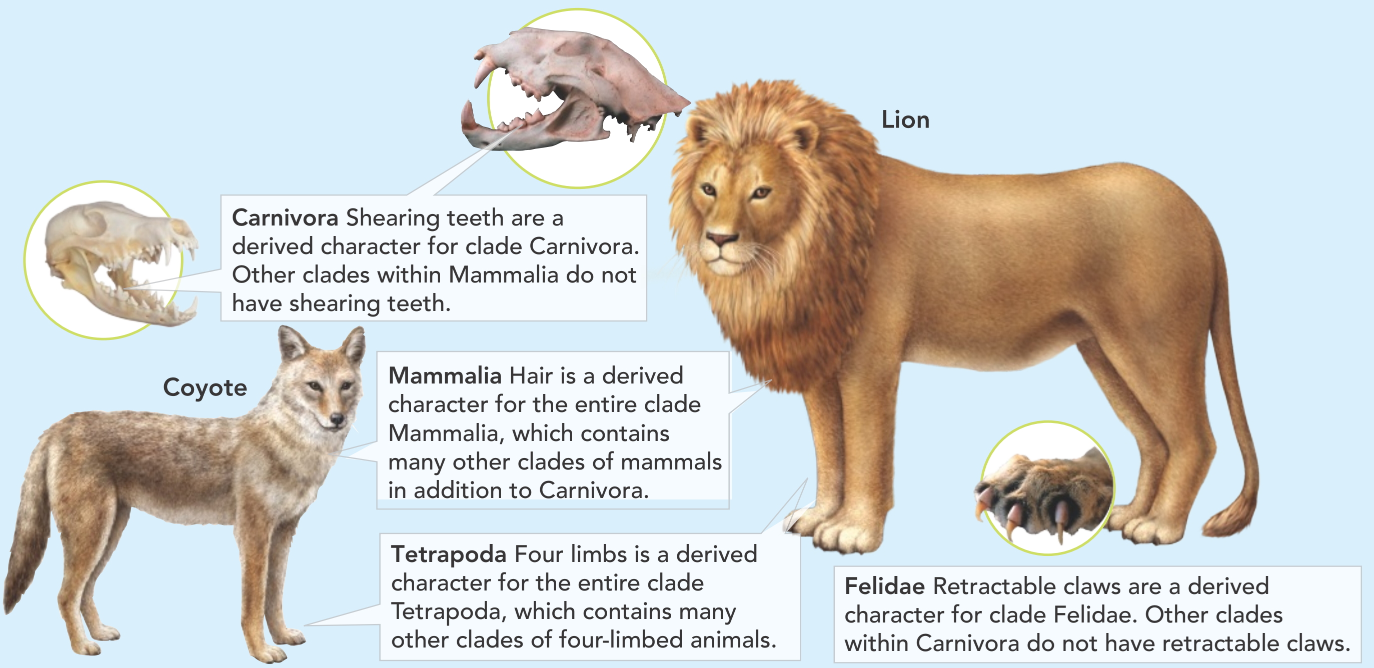
BUILD VOCABULARY

Academic Words The term derived refers to a beginning or origin. Some English words, for example, are derived from other languages. A **derived character** is a trait that has a common origin in a clade.

Figure 19-7

Derived Characters

Shared characters put both lions and coyotes in several clades, including Tetrapoda (four legs), Mammalia (hair), and Carnivora (shearing teeth). Only the lion, however, has retractable claws, a derived character for the clade Felidae.



Interpreting Cladograms Look at **Figure 19-8**, which shows a simplified phylogeny of the cat family. The lowest branching point represents the last common ancestor of all four-limbed animals, which are members of the clade Tetrapoda. The forks in this cladogram show the order in which various groups branched off from the tetrapod lineage. The positions of various characters in the cladogram reflect the order in which those characteristics arose. Hair, for example, is a defining character for the clade Mammalia. In the lineage leading to cats, specialized shearing teeth evolved before retractable claws.

Furthermore, each derived character listed along the main trunk of the cladogram defines a clade. Retractable claws is a derived character shared only by the clade Felidae. Derived characters that occur "lower" on the cladogram than the branch point for a clade are not derived for that particular clade. Note that hair is a derived character for the entire clade Mammalia, but it is not a derived character for the branch of mammals in the clade Carnivora.

Clades and Traditional Groups Which Linnaean groupings form clades, and which do not? Remember that a true clade must contain an ancestral species and *all* of its descendants, with no exceptions. It also must exclude all species that are not descendants of the original ancestor. Cladistic analysis shows that many traditional taxonomic groups form valid clades. For example, Linnaean class Mammalia corresponds to clade Mammalia.

CASE STUDY

Figure 19-8

Interpreting a Cladogram

In a cladogram, all organisms in a clade share a set of derived characters. Notice that smaller clades are nested within larger clades. **Interpret Visuals** For which clade is an amniotic egg a derived character? Is the duck-billed platypus a member of the clade Amniota? Explain.

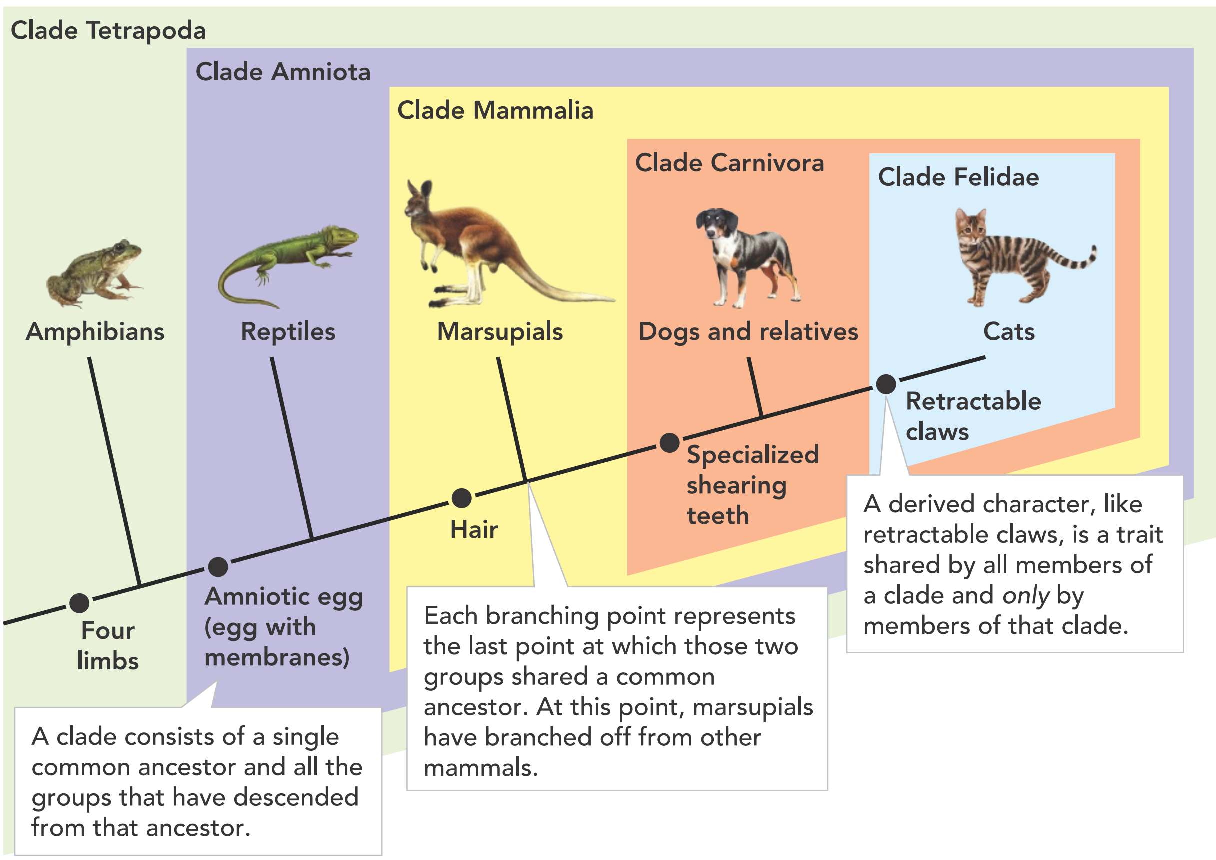
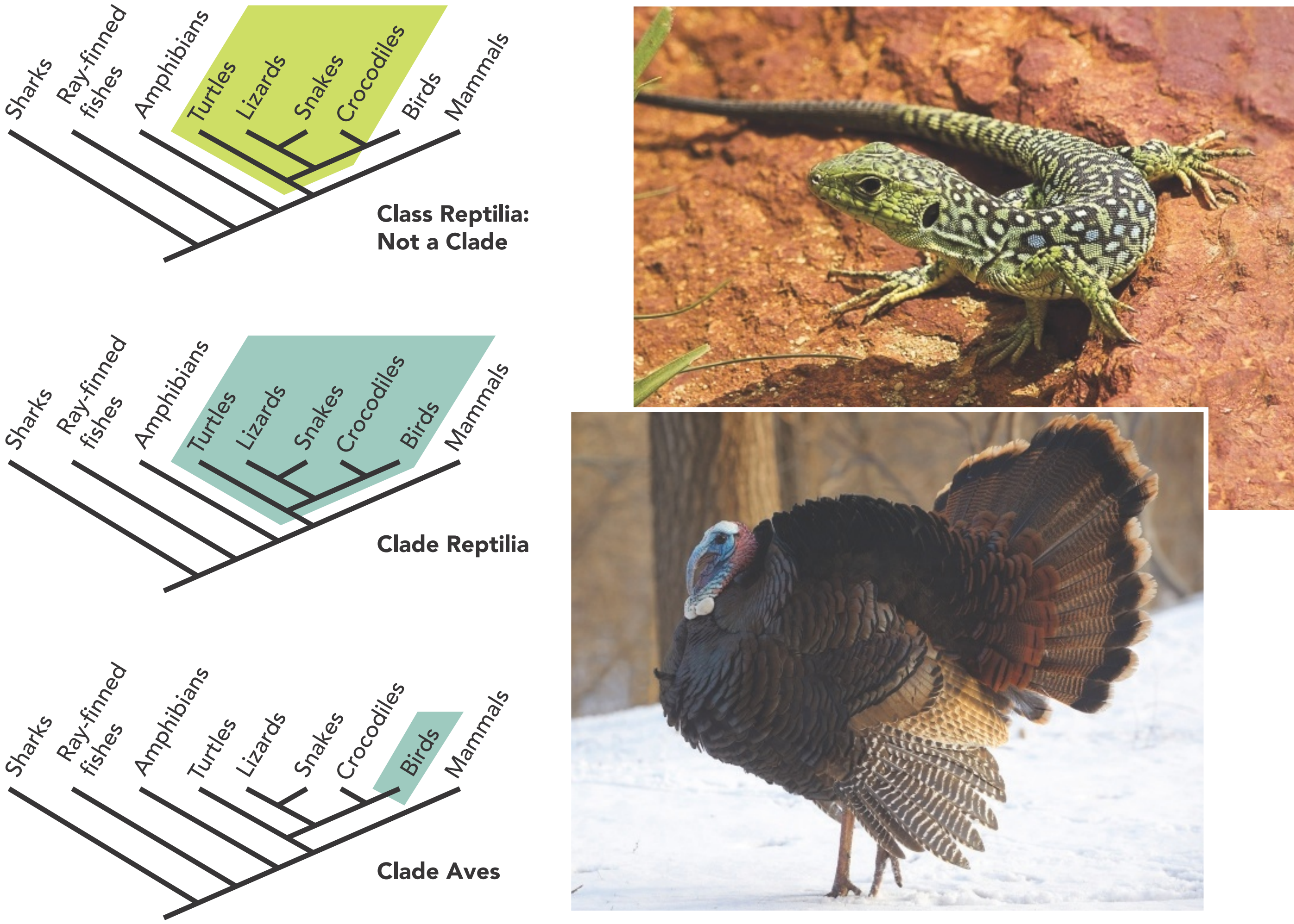


Figure 19-9

Clade or Not?

A clade includes an ancestral species and all its descendants. Linnaean class Reptilia is not a clade because it does not include modern birds. Clades Reptilia and Aves are valid clades. Note that these cladograms include living groups only.



In other cases, however, traditional groups are not valid clades, as **Figure 19-9** shows. Today's reptiles are all descended from a common ancestor. Birds were traditionally treated as a separate class, Aves. But birds are descended from that same common ancestor as reptiles. So class Reptilia, without birds, is not a clade. There are several valid clades that *do* include birds: Aves, Dinosauria, and the clade Reptilia. Can you now see why biologists say that birds are dinosaurs?

You may wonder: class Reptilia, clade Reptilia—who cares? But these names represent important concepts in classification. Remember that modern biologists want classification systems to represent the evolutionary relationships among organisms. Accurate understanding of those relationships can be very helpful in comparing and contrasting characteristics among and between clades.

READING CHECK **Compare** What do all clades have in common, regardless of their size?

INTERACTIVITY

Classify five shark species based on morphology and DNA analysis.

DNA in Classification

The examples of cladistic analysis we've discussed so far are based largely on physical characteristics like skeletons and teeth. However, the goal of modern systematics is to understand the evolutionary relationships of *all* life on Earth, including bacteria, plants, worms, and octopuses. How can we devise hypotheses about the common ancestors of organisms that have no physical similarities?

Genes as Derived Characters Remember that all organisms carry genetic information in DNA. They inherit genes from earlier generations. As scientists have discovered, a wide range of organisms share genes that can be used to determine evolutionary relationships.

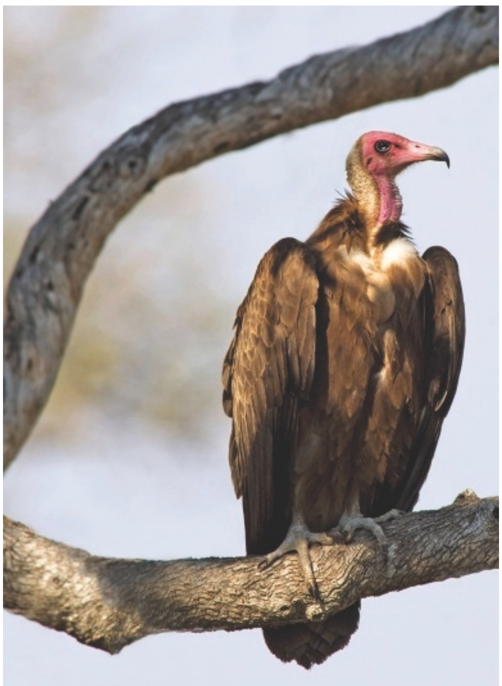
For example, all eukaryotic cells have mitochondria, and all mitochondria have their own genes. Because all genes mutate over time, shared genes contain differences that can be treated as derived characters in cladistic analysis. For that reason, similarities and differences in DNA can be used to develop hypotheses about evolutionary relationships. ***In general, the more derived genetic characters two species share, the more recently they shared a common ancestor and the more closely they are related in evolutionary terms.***

Figure 19-10

DNA and Classification

The two vultures appear very different from the stork. However, DNA analysis suggests that American vultures, such as the turkey vulture, are more closely related to storks than they are to other vultures.

American turkey vulture (*Cathartes aura*)



African hooded vulture (*Necrosyrtes monachus*)

Saddle-billed stork (*Ephippiorhynchus senegalensis*)

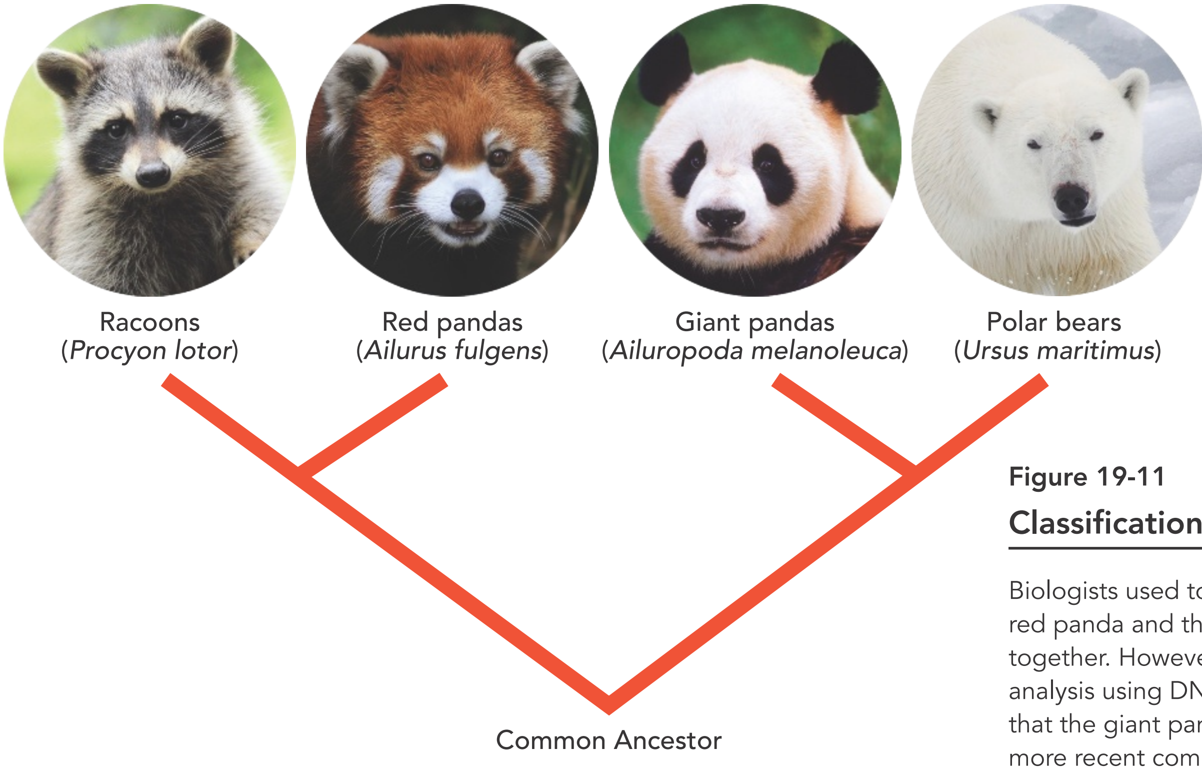


Figure 19-11

Classification of Pandas

Biologists used to classify the red panda and the giant panda together. However, cladistics analysis using DNA suggests that the giant panda shares a more recent common ancestor with bears than with either red pandas or raccoons.

New Techniques Suggest New Trees DNA analysis has helped to make evolutionary trees more accurate. Consider, for example, the birds shown in **Figure 19-10**. The hooded vulture from Africa looks a lot like the American turkey vulture. Both were traditionally classified in the Falcon clade. However, American vultures have a peculiar behavior: When they get overheated, they urinate on their legs, allowing evaporation to cool them down. Storks share this behavior, while hooded vultures and other vultures from Africa do not. Could the behavior be a clue to the real relationships between these birds?

Biologists solved the puzzle by analyzing DNA from all three species. Molecular analysis showed that the DNA from American vultures is more similar to the DNA of storks than to the DNA of African vultures. DNA evidence therefore suggests that American vultures and storks share a more recent common ancestor than the American and African vultures do.

Often, scientists use DNA evidence when anatomical traits alone cannot provide clear answers. Giant pandas and red pandas, for example, puzzled taxonomists for many years. These species share anatomical similarities with both bears and raccoons, and both have peculiar wrist bones that work like a human thumb. DNA analysis revealed that the giant panda shares a more recent common ancestor with bears than with raccoons. DNA places red pandas, however, outside the bear clade. So giant pandas have been reclassified, and are now placed with other bears in the clade Ursidae, as shown in **Figure 19-11**. The red panda is now placed in a different clade that also includes raccoons, seals, and weasels.

READING CHECK **Summarize** Why is DNA analysis useful for classification?

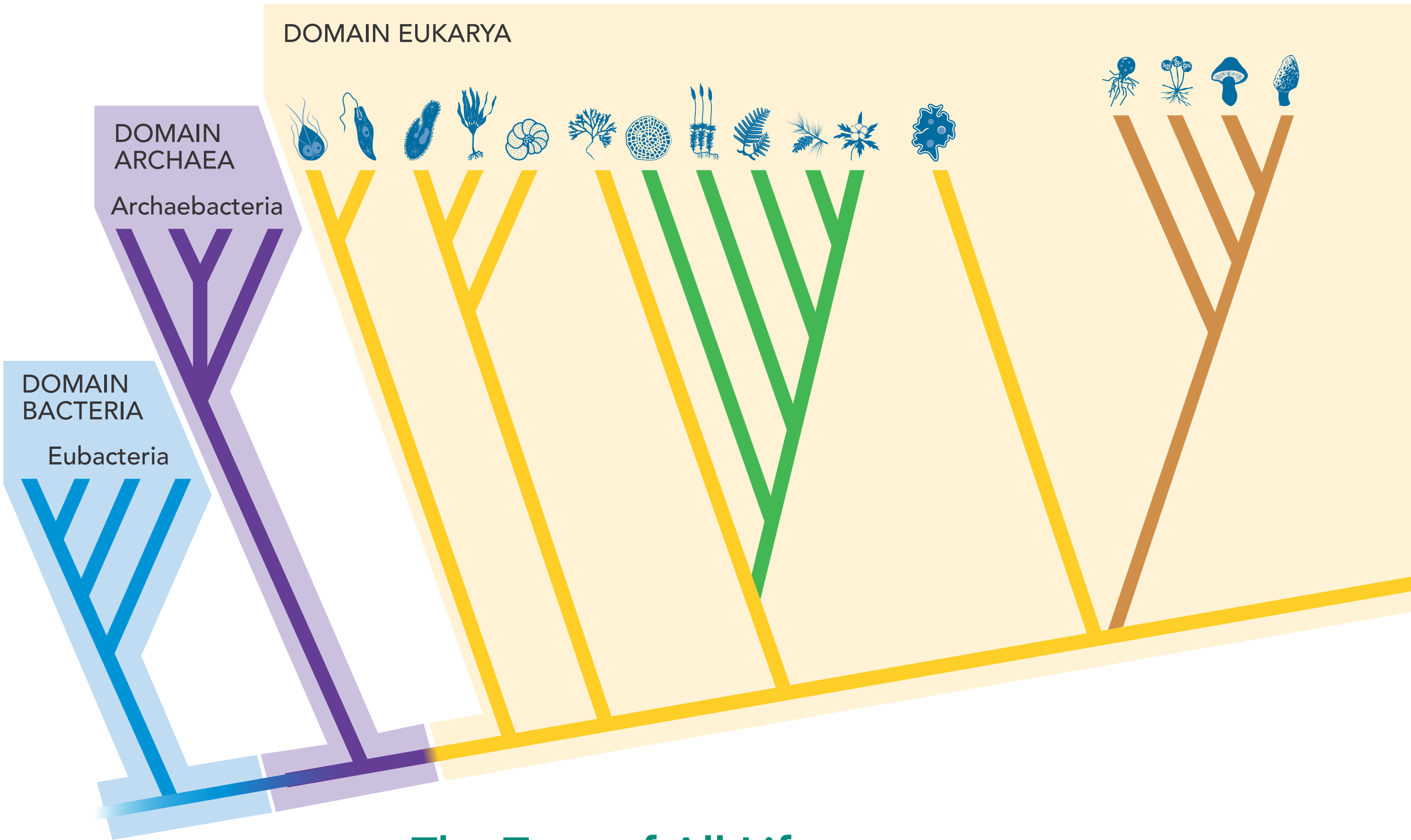


Figure 19-12

Tree of Life

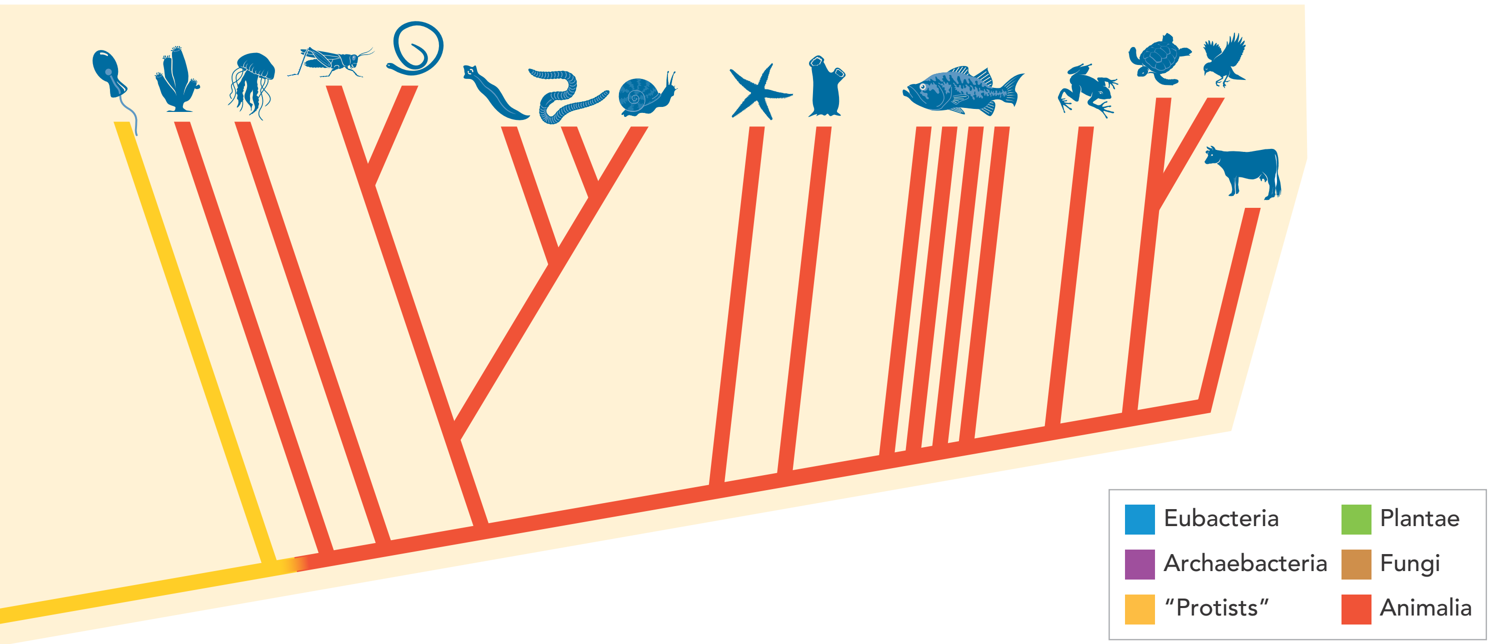
The tree of life shows the latest hypothesis about how major groups of organisms are related to one another. Note that both domain and kingdom designations are shown. **Classify** Which of the six kingdoms contains organisms that are not all in the same clade?

The Tree of All Life

Modern evolutionary classification is a rapidly changing science with a difficult goal—to present all life on a single evolutionary tree. As new discoveries are made, biologists change the way organisms are grouped. Sometimes they change the names of groups. Remember that cladograms are visual presentations of hypotheses about relationships, and not final. ***The tree of all life illustrates current hypotheses regarding evolutionary relationships among the taxa within the three domains of life.*** **Figure 19-12** shows a simplified version of the tree.

Domain Bacteria Members of the domain Bacteria are unicellular and prokaryotic. Their cells have thick, rigid walls that surround a cell membrane. The cell walls contain a substance known as peptidoglycan (pep tih doh GLY kun). These bacteria range from free-living soil organisms to deadly parasites. Some photosynthesize, while others do not. Some need oxygen to survive, while others are killed by oxygen. This domain corresponds to the old kingdom Eubacteria.

Domain Archaea Like Bacteria, members of the domain Archaea (ahr KEE uh) are also unicellular and prokaryotic. However, Archaea live in some of Earth's most extreme environments, such as volcanic hot springs, brine pools, and black organic mud totally devoid of oxygen. Indeed, many archaea can survive only in the absence of oxygen. Their cell walls lack peptidoglycan, and their cell membranes contain unusual lipids that are not found in any other organisms. The domain Archaea corresponds to the old kingdom Archaebacteria.



Domain Eukarya The domain Eukarya consists of all organisms that have a nucleus. It comprises the four remaining major groups of the old six-kingdom system: Protista, Fungi, Plantae, and Animalia.

"Protists": Unicellular Eukaryotes Remember that this old kingdom is *not* a valid clade. People still use the name "protists" casually to refer to these organisms. However, scientists have known for years that many of these organisms are fundamentally different from one another, so the casual name has little meaning. Figure 19-12 shows that current cladistic analysis divides these organisms into at least five clades. The positions of these groups on the cladogram reflect current hypotheses about their evolutionary histories.

The protists are divided into several separate clades that also include other types of species. Most clades are unicellular, but one clade, the brown algae, is multicellular. Some are photosynthetic, while others are heterotrophic.

Fungi Members of the kingdom Fungi are heterotrophs with cell walls containing chitin. Mushrooms are multicellular. Some fungi, including yeasts, are unicellular. Fungal ecology is complicated, although most obtain nutrients from organic matter. Many fungi once thought to be just decomposers also act as symbionts with the roots of plants.

Plantae Members of the kingdom Plantae are autotrophs with cell walls that contain cellulose. Autotrophic plants photosynthesize using chlorophyll. The plant kingdom includes green algae, mosses, ferns, cone-bearing plants, and flowering plants. Some species of green algae are unicellular, and others are multicellular. All other types of plants are multicellular.

Animalia Members of the kingdom Animalia are multicellular and heterotrophic. Animal cells do not have cell walls. Most animals can move about, at least for some part of their life cycle. There is incredible diversity within the animal kingdom.

READING TOOL

Use the visual to explain why "Protists" do not form a valid clade.

HS-LS4-1

Argument-Based Inquiry Guided Inquiry

Construct a Cladogram

Problem How can you use a cladogram to model the evolutionary relationship among species?

In this lab, you will make models of organisms to show evolutionary relationships. Then you will study a model made by another group. You will use your skills of observation and logical reasoning to identify the derived characters and construct a cladogram.

You can find this lab in your digital course.

A Revised Tree of Life The tree shown in Figure 19-12 is drawn to clearly illustrate current hypotheses about relationships among the groups of organisms that you are likely to know. That kind of tree, however, gives a couple of incorrect impressions. For one thing, its style of presentation suggests that mammals are the latest and greatest living things. It also misrepresents the relative numbers of organisms belonging to different clades. There are almost unimaginably large numbers of species in domains Eubacteria and Archaea, and equally overwhelming numbers of single-celled eukaryotes. Those clades literally dwarf the clades of multicellular fungi, plants, and animals that most people know best.

So what's the solution? What kind of cladogram could show a more accurate picture of the full diversity of life? To more accurately portray the living world, that kind of tree would spread organisms out to reflect the genetic diversity that underlies major differences in biochemistry and cell structure. The difficulty is that if we draw such a tree in the "normal" style for cladograms, it would spread out over several pages. One solution, proposed by biologist David Hillis, of the University of Texas at Austin, is shown in **Figure 19-13**. It provides a truer representation of the full diversity we know exists among living organisms.

HS-LS1-4

LESSON 19.2 Review

KEY IDEAS

1. How is the goal of evolutionary classification different from Linnaean classification?
2. What is the relationship between a clade and a cladogram?
3. How do taxonomists use the DNA sequences of species to determine how closely two species are related?
4. How is the tree of life related to the work of Charles Darwin?

CRITICAL THINKING

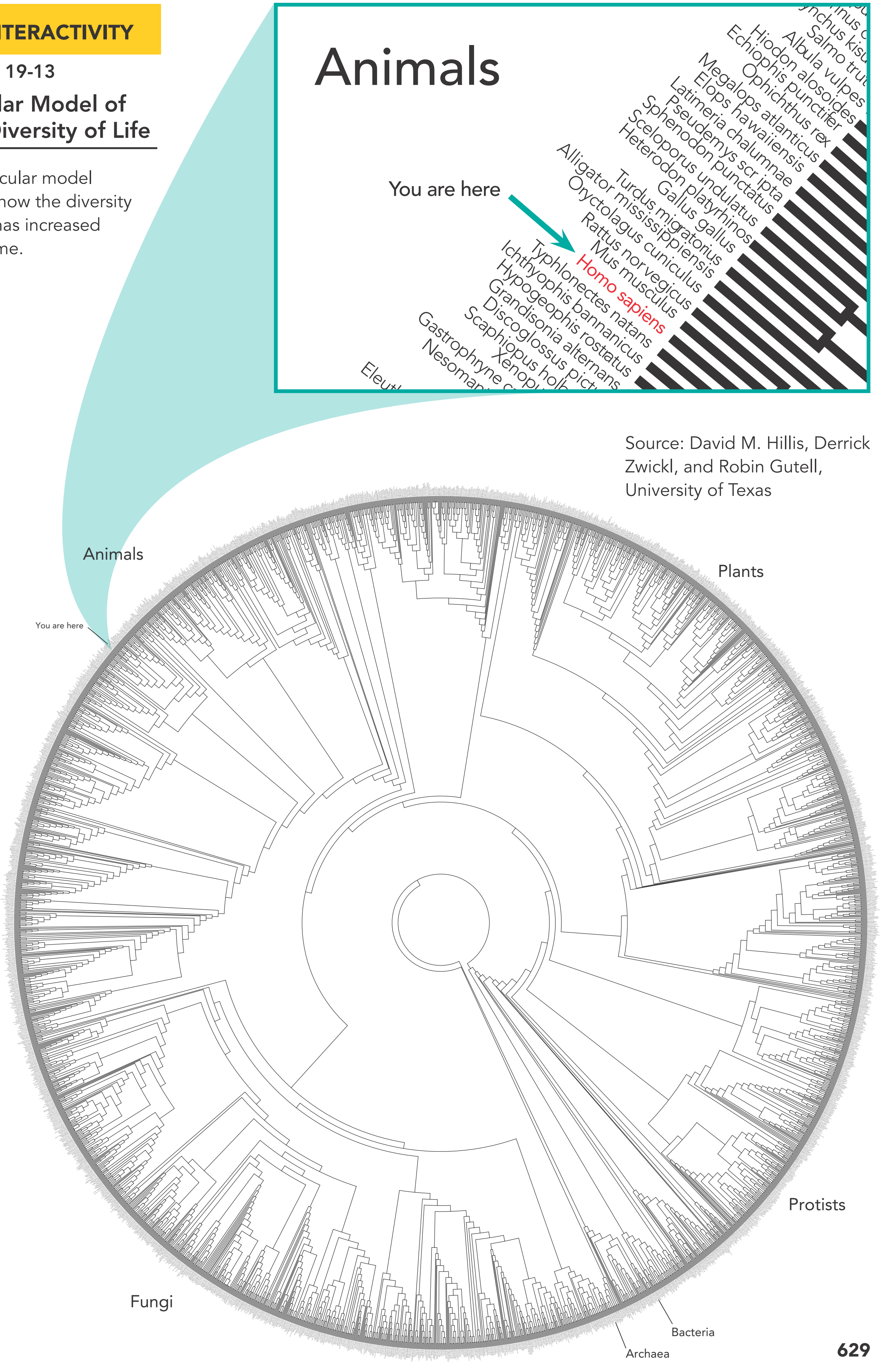
5. **Apply Scientific Reasoning** The family Camelidae includes camels and llamas. Do all the living members of the family form a clade? Explain.
6. **CASE STUDY** A scientist studies the DNA in corresponding genes of a platypus, a beaver, and a duck. The DNA from which two species are most likely to be most similar? Explain your answer.

INTERACTIVITY

Figure 19-13

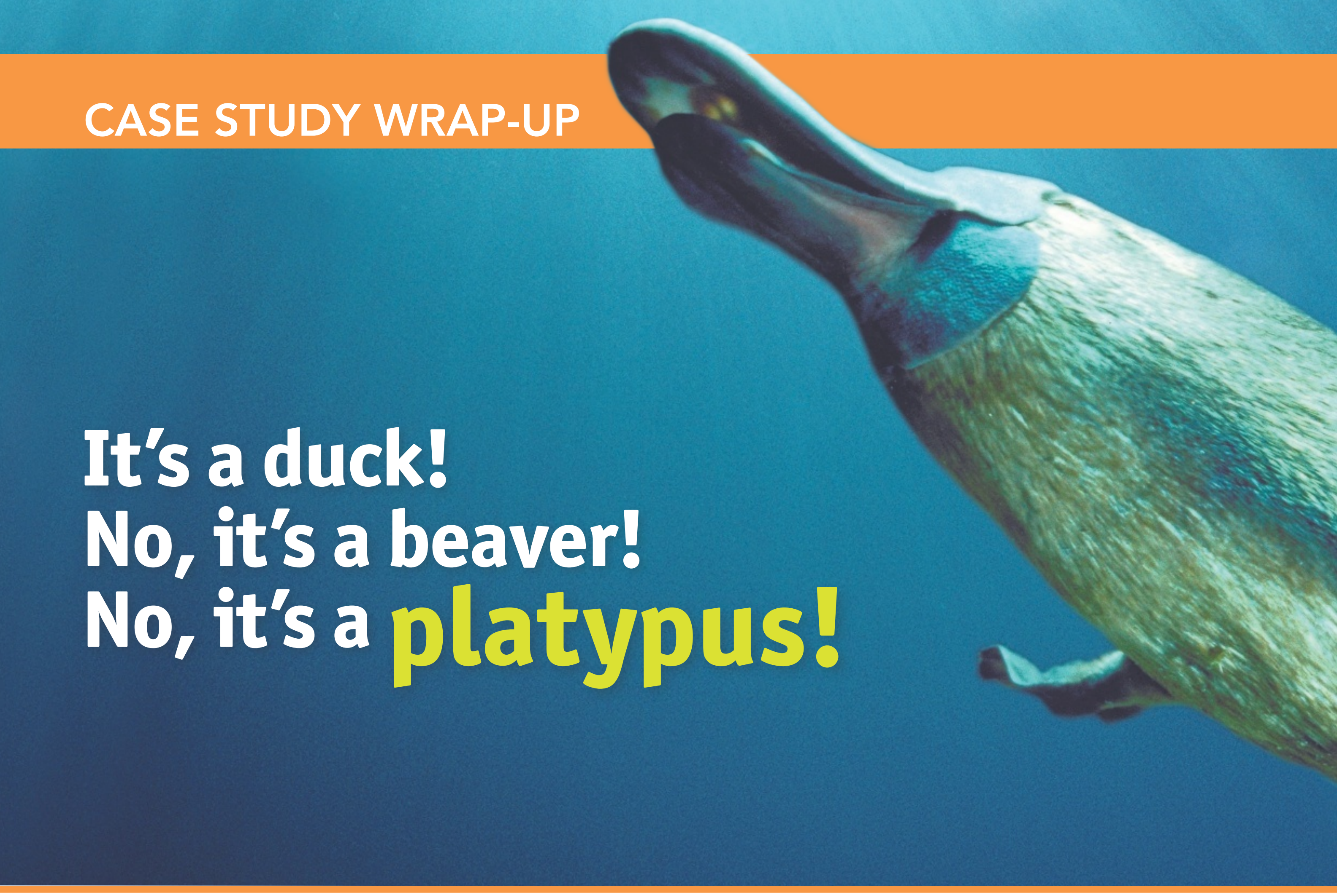
Circular Model of the Diversity of Life

This circular model shows how the diversity of life has increased over time.



Source: David M. Hillis, Derrick Zwickl, and Robin Gutell, University of Texas

CASE STUDY WRAP-UP



It's a duck! No, it's a beaver! No, it's a platypus!

Platypus lay eggs, yet suckle their young. These characteristics show how mammalian reproductive systems have evolved over time.

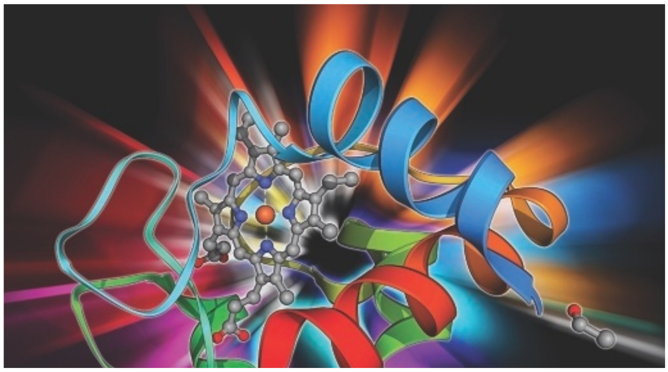
HS-LS4-1

Make Your Case

Carolus Linnaeus lived long before evolutionary theory and genetics provided a framework for biology. So, Linnaeus classified organisms based on shared visible characteristics, and had no scientific way to determine the relative importance of those characteristics in grouping organisms. No wonder it was difficult to use his system to classify oddballs like the platypus! Modern taxonomy includes anatomical, physiological, and genetic characteristics, and uses evolutionary theory to evaluate the relative importance of those traits in classification.

Develop a Solution

1. **Construct an Explanation** Why did scientists in the 1800s struggle to classify the platypus, and how does evolutionary classification inform that task?
2. **Develop a Model** All mammals except monotremes give birth to live young. Research other shared and derived mammalian traits and construct a simple cladogram that shows the relationships among the three main groups of mammals: marsupials, monotremes, and placentals.



Technology on the Case

Genes, Computers, and Taxonomy

Early taxonomists relied on visible differences among organisms that could be seen with the naked eye. The invention and refinement of microscopes, the development of evolutionary theory, the ability to study amino acid sequences of ancient proteins, and techniques that enabled us to "read" information coded in DNA all triggered dramatic changes in the ways scientists name and classify organisms.

In recent years, advances in molecular biology and computer science have fueled incredible growth and change in taxonomy. A few decades ago, scientists struggled to study the amino acid sequences in ancient proteins like cytochrome c. Today, automated technology is able to sequence entire genomes in a few hours! This technology puts an astonishing amount of data at the disposal of taxonomists. A great gift to taxonomy? Absolutely! But the volume of those data creates a question: How do we understand and interpret all that information?

Recall that modern taxonomy attempts to classify organisms into groups that represent evolutionary lines of descent. For traits such as bones and teeth, fossils can help determine which traits are old and shared by many organisms, and which are newer and shared only by smaller taxa.

But how can researchers make those kinds of determinations with DNA sequences? Computers can sort through vast amounts of data … but HOW should they do the sorting? Which DNA sequences are old, shared traits? Which are newer, derived traits? The emerging rules are complicated … and the evolving science of taxonomy is rising to the challenge!

Careers on the Case

Work Toward a Solution

Many scientists might study the platypus or another species that poses puzzling questions. However, the task of classifying the species belongs to the taxonomist.

Taxonomist

Studying biology in high school and college is the first step to becoming a taxonomist. Taxonomists study further to specialize in the taxonomy of plants, insects, or other animals. Taxonomists may work for universities, the government, museums and, zoos or research firms. Strong research skills and a love of nature are keys to success in this career.

VIDEO

Learn more about taxonomists and related careers.

STUDY GUIDE

Lesson Review

Go to your Biology Foundations Workbook for longer versions of these lesson summaries.

19.1 Finding Order in Biodiversity

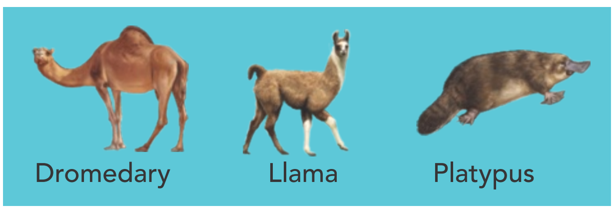
Scientists found that they needed a universal naming system to clearly communicate with each other about the organisms they discovered and studied. In the Linnaean system of organization, each living thing is given a two-part name consisting of its genus and species. This system is called binomial nomenclature.

In addition to naming organisms, biologists try to classify them into larger groups that have biological meaning. The science of naming and grouping organisms is systematics.

Linnaeus's original classification system eventually expanded to include seven hierarchical taxa: species, genus, family, order, class, phylum, and kingdom. The first classification system consisted of only two kingdoms, Plantae and Animalia.

Over time, the classification system expanded from a two-kingdom system to a six-kingdom system. Then biologists added a new level that is larger and more inclusive than a kingdom—the domain. Under this system there are three domains: Bacteria, Archaea, and Eukarya.

- taxonomy
- binomial nomenclature
- genus
- systematics
- taxon
- family
- order
- class
- phylum
- kingdom
- domain



Review What is the name of the most specific taxon that contains all these animals?

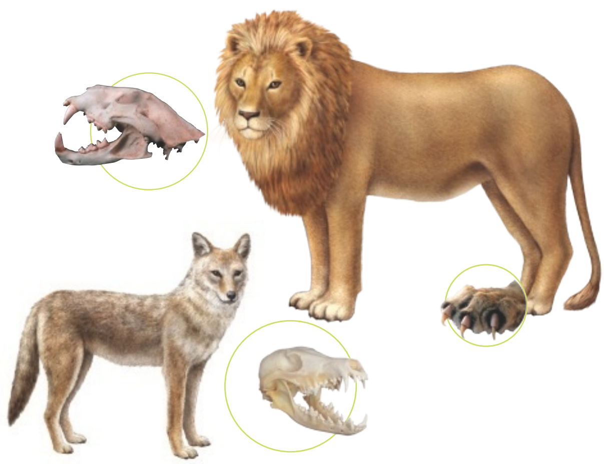
19.2 Modern Evolutionary Classification

In modern evolutionary classification, organisms are grouped into categories that reflect their evolutionary descent. This system places organisms into higher taxa whose members are more closely related to one another than they are to members of any other group. The larger the taxon, the more ancient the common ancestor of the group.

A cladogram shows evolutionary lineages that branched off from common ancestors. Each branch in a cladogram is associated with a derived character, a trait that arose in the most recent common ancestor and was passed to its descendants. In general, the more derived characteristics two species share, the more closely they are related.

Cladograms can be assembled into a tree of all life. Whether displayed as a form that branches outward and upward or as a circle branching from the center, the tree of all life shows the current hypotheses regarding evolutionary relationships within the three domains of life: Archaea, Bacteria, and Eukarya.

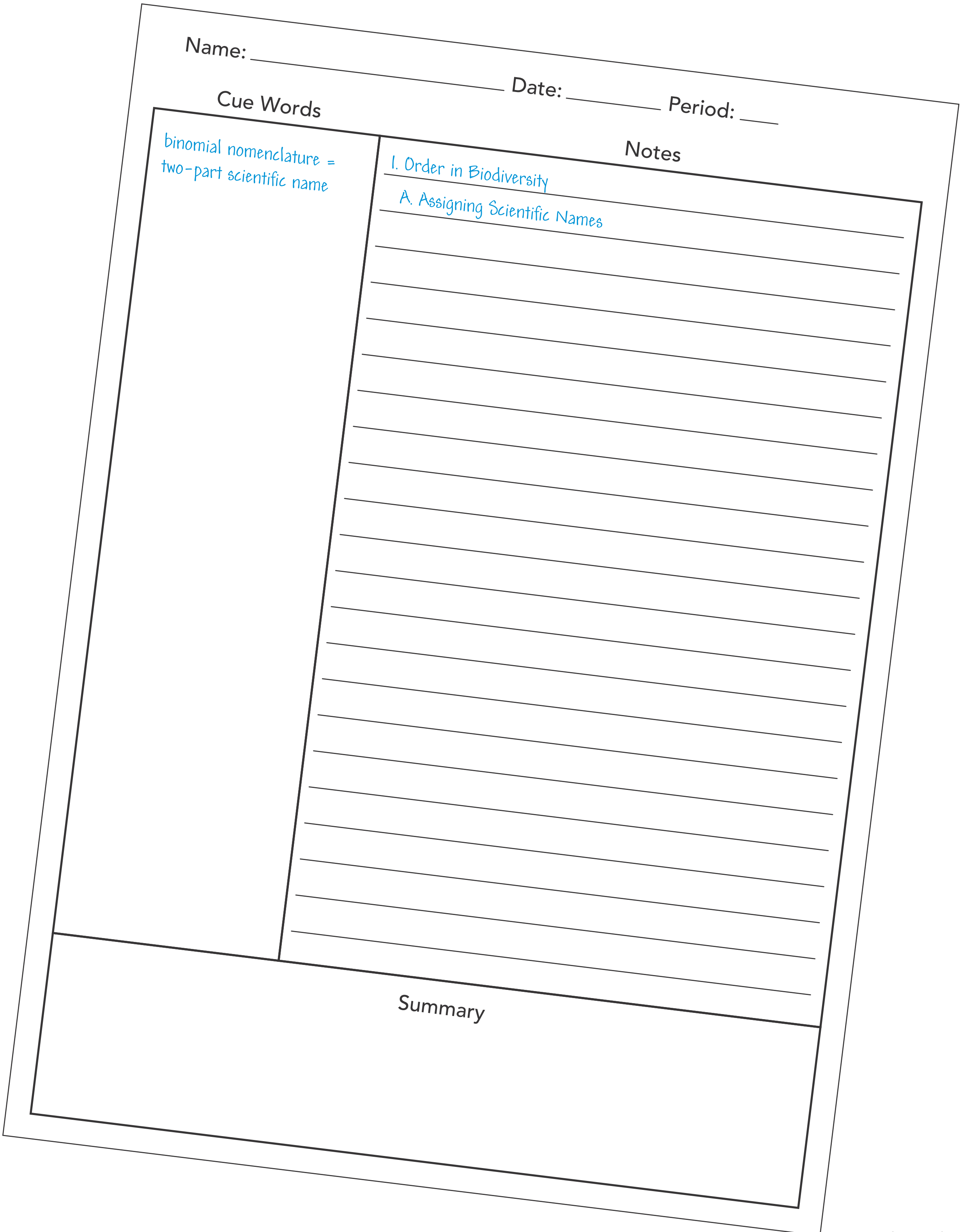
- phylogeny
- clade
- cladogram
- derived character



Apply Concepts Coyotes and lions are both members of the clade Carnivora. What other clades include both animals? Name some other animals that are members of these clades.

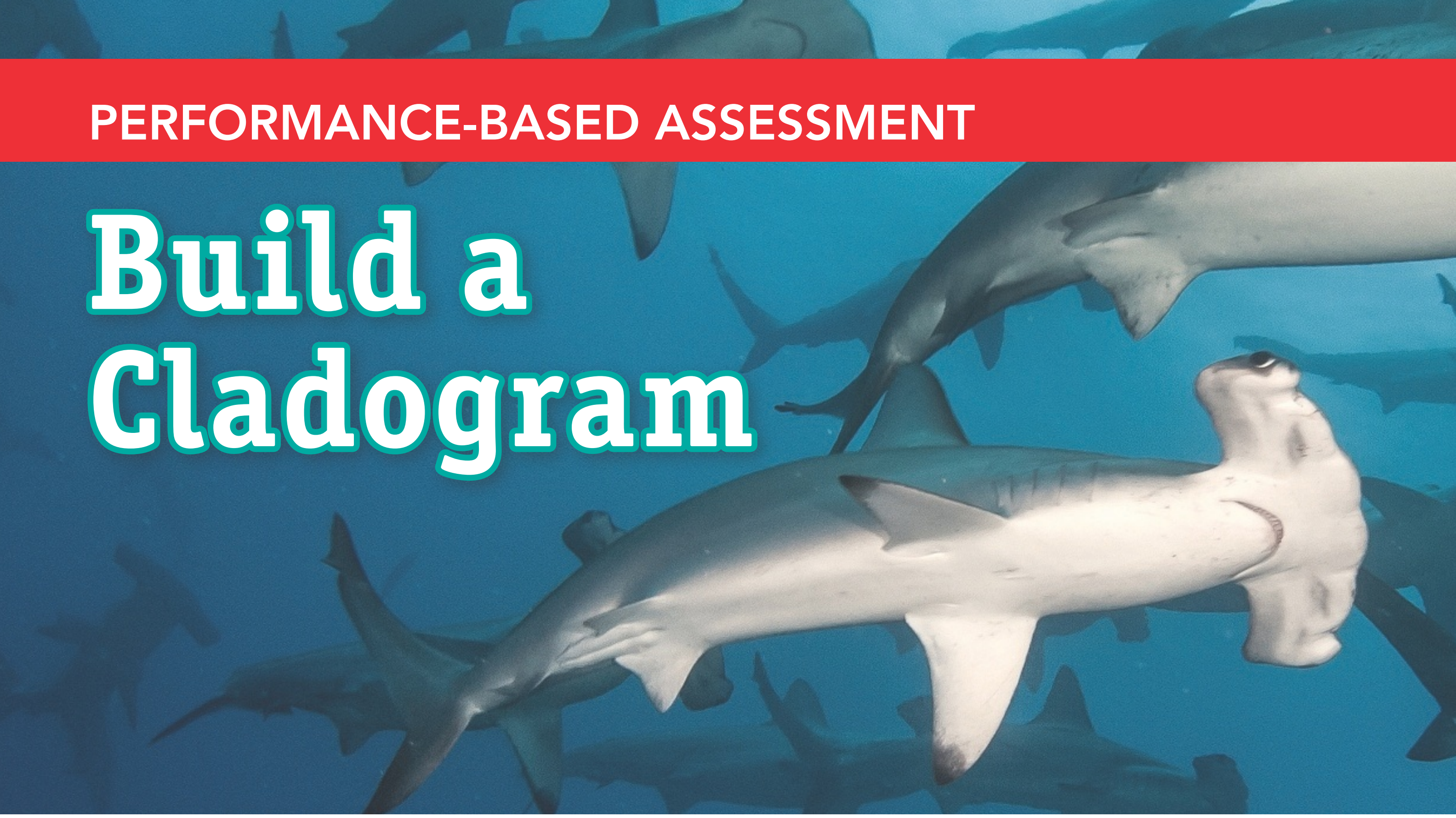
Organize Information

Complete the Cornell notes for this chapter. First, finish the notes on main ideas and details. Next, select the key points from your notes. Finally, write a summary of the chapter based on your key points.



PERFORMANCE-BASED ASSESSMENT

Build a Cladogram



Construct a Model

HS-LS4-1, CCSS.ELA-LITERACY.SL.9-10.4, CCSS.ELA.LITERACY.SL9-10.5, CCSS.ELA-LITERACY.RST.9-10.7, CCSS.ELA-LITERACY.WHST.9-10.2

STEM A cladogram is a model that presents a hypothesis about how groups of organisms are related. Members of each clade should be more closely related to each other than they are to members of any other clade.

To construct a cladogram, scientists focus on derived characters that define evolutionary lineages. For example, a backbone, or vertebral column, formed by vertebrae is a derived character for the clade Vertebrata. All members of that clade, and only members of that clade, have a vertebral column. This means that a vertebral column evolved once in the common ancestor shared by all vertebrates. That character was then passed on to all descendants of that common ancestor.

How is the clade Vertebrata divided into smaller clades? By using other traits that later evolved in some, but not all, vertebrates. Use the table of characters to build a cladogram model that shows the evolution of vertebrates.

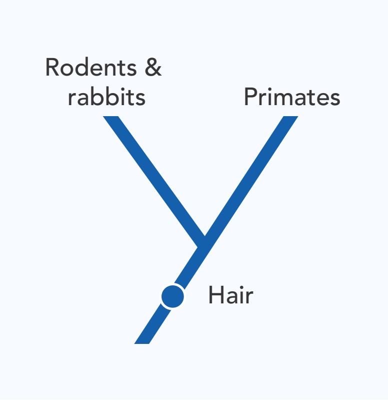
	Vertebrate?	Bony skeleton?	Four limbs?	Amniotic egg?	Hair?	Eggs with shells?
Sharks and relatives	Yes	No	No	No	No	No
Ray-finned fishes	Yes	Yes	No	No	No	No
Amphibians	Yes	Yes	Yes	No	No	No
Crocodiles	Yes	Yes	Yes	Yes	No	Yes
Dinosaurs and birds	Yes	Yes	Yes	Yes	No	Yes
Primates	Yes	Yes	Yes	Yes	Yes	No
Rodents	Yes	Yes	Yes	Yes	Yes	No

SCIENCE PROJECT

1. **Draw Conclusions** Of the six characters listed in the table, which was found in the common ancestor of all seven groups? Explain your inference.

2. **Infer** Traits found in some or all vertebrate groups include a bony skeleton, four limbs, and an amniotic egg. Which evolved first? Which evolved next? Explain your inference.

3. **Use a Model** The diagram shows a small section of the cladogram that explains the evolution of the seven animal groups. What does this section show about the evolution of primates, rodents, and rabbits?



4. **Develop a Model** Expand your cladogram to show the evolutionary lineages of all seven groups listed in the table. Use labels at branch points in the lineages to show the derived characters that evolved over time.

5. **Communicate Information** Research the evolution of vertebrates, focusing on the evolution of the traits used in your model in the fossil record. In an oral report or written paragraph, use the cladogram to organize and present the results of your study.

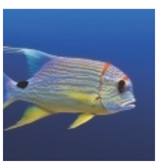
CHAPTER 19
ASSESSMENT

KEY QUESTIONS AND TERMS

19.1 Finding Order in Biodiversity

1. The scientific name for a species has how many parts?
   a. one c. three
   b. two d. four
2. Arrange the taxa from most specific to most general.
   class family genus kingdom
   order phylum species
3. Study the picture.

   The animals shown here are grouped together in the same
   a. family. c. genus.
   b. phylum. d. kingdom.
4. How does the modern system of classification compare to Linnaeus's original system?
5. How have the organisms in the old Kingdom Monera been reclassified today?
6. What are the three domains?
7. Which four of the six kingdoms are grouped together in the same domain?
8. Identify the kingdom for each of these organisms.

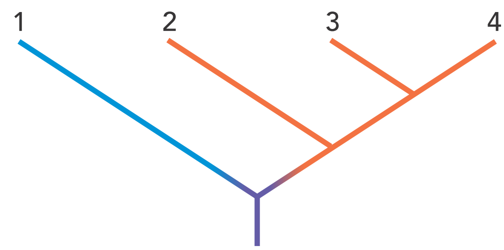
a. 
c. 
b. 
d. 

19.2 Modern Evolutionary Classification

HS-LS4-1

9. A common ancestor and all its descendants make up a
   a. clade. c. kingdom.
   b. domain. d. order.
10. The members of which domain are most apt to live in harsh habitats, such as brine pools or volcanic hot springs?
    a. Archaea c. Eukarya
    b. Bacteria d. Monera
11. Which cell structure distinguishes members of domain Eukarya from other organisms?
    a. cell wall
    b. cell membrane
    c. cytoplasm
    d. nucleus

Use the diagram to answer questions 12 and 13.



12. What do the lines in the diagram represent?
13. What is represented by the intersection of two lines in the diagram?
14. How do derived genetic characters help reveal evolutionary relationships?
15. Why can differences in mitochondrial DNA be used as derived characters?
16. What does a model called the tree of life show about all living things?
17. Give an example of a kingdom from an older classification scheme that is not a valid clade. Why is it not valid?
18. What does the term *phylogeny* describe about organisms?
19. How is a derived character different from other shared traits of a clade?

CRITICAL THINKING

HS-LS4-1

20. **Compare and Contrast** How are members of the domains Bacteria and Archaea alike? How are they different?

21. **Apply Concepts** Both snakes and worms are tube shaped and lack legs. How could you determine whether their similarity in shape means that they share a recent common ancestor?

22. **Ask Questions** What questions would Linnaeus ask to determine a classification? What questions would a modern taxonomist ask?

23. **Construct an Explanation** What are the advantages of classifying species according to their evolutionary relationships, rather than their physical or behavioral similarities?

24. **Use Models** Taxa act as a model of evolutionary relationships. Scientists now use the taxonomic category of the domain to organize the kingdoms of life. How is the domain an improvement to the model?

25. **Apply Scientific Reasoning** A cladogram for bats includes the development of wings for flight. Birds also fly, so should they also be included in the cladogram? Explain your reasoning.

26. **Synthesize Information** Why is kingdom "Protista" not an example of a clade?

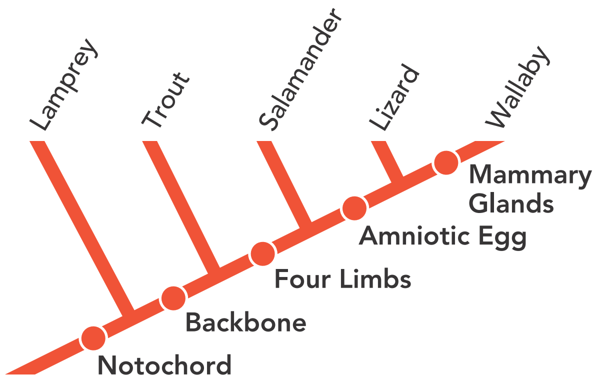
27. **Ask Questions** Corals are multicellular organisms that live underwater. As adults they do not move from place to place. What questions would you ask to help you classify them into the proper kingdom?

28. **Evaluate Claims** A student claims that beaks, hollow bones, and feathers are derived characters of birds, which are members of the clade *Theropoda*. What evidence would support this claim?

29. **Compare and Contrast** People often use a diagram called a family tree as a model of their extended family. The diagram shows parents, children, siblings, and other family relationships. How does a family tree compare to the tree of life?

30. **Infer** Birds, reptiles, and mammals are each members of one class only. Fishes, however, are organized into three classes. What can you infer about fishes from their diverse classifications?

Use the cladogram shown below to answer questions 31–33.



31. **Interpret Diagrams** Of the characteristics listed in the cladogram, which do lizards and salamanders have in common?

32. **Draw Conclusions** The diagram identifies five derived characters. What conclusion does the diagram support about the order in which the five derived characters evolved?

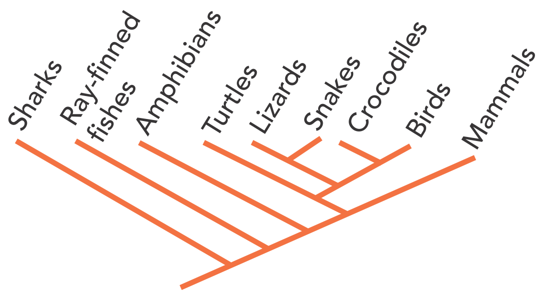
33. **Integrate Information** A tuatara has a backbone and four limbs, but does not develop from an amniotic egg. Where does it fit in the cladogram? Explain.

CROSSCUTTING CONCEPTS

34. **Systems and System Models** How is the classification of an organism in the Linnaean system similar to the street address of a house? (**Hint:** Think of an address used for international mail.)

35. **Patterns** What evolutionary pattern does every cladogram show?

Use the diagram to answer questions 36–38.



36. **Systems and System Models** Turtles, lizards, snakes, and crocodiles are all classified as reptiles. Why is this group of animals not a clade?

37. **Stability and Change** Did ray-finned fishes evolve from sharks? Use the diagram to support your answer.

38. **Systems and System Models** Mammals have four limbs, give birth to live young, and make milk for their young. How could you determine which of these traits, if any, is a derived character of the clade of mammals?

MATH CONNECTIONS

Analyze and Interpret Data

CCSS.MATH.CONTENT.MP4

The table describes the characteristics of five different organisms. Use the table to answer questions 39–41.

	Turtle	Lamprey	Frog	Fish	Cat
Hair	No	No	No	No	Yes
Amniotic egg	Yes	No	No	No	Yes
Four legs	Yes	No	Yes	No	Yes
Jaw	Yes	No	Yes	Yes	Yes
Vertebrae	Yes	Yes	Yes	Yes	Yes

39. **Interpret Data** The first column lists derived characters that can be used to make a cladogram of vertebrates. Which characteristic is shared by the most organisms? Which is shared by the fewest?

40. **Develop a Model** Use the data to sequence the organisms from the most recently evolved to the most ancient.

41. **Draw Conclusions** Which of the characteristics shown in the table was the most likely to have evolved first? Which evolved most recently? Explain.

A scientist analyzes the DNA of complementary mitochondrial genes from five organisms, labeled A to E. Each organism represents a different species. The data table shows the number of base-pair differences in the DNA of any two of the organisms. Use the data table to answer questions 42–44.

	A	B	C	D	E
A	×	18	3	29	10
B	18	×	26	4	12
C	3	26	×	20	13
D	29	4	20	×	11
E	10	12	13	11	×

42. **Interpret Data** Identify the two most recent evolutionary events that the data suggest.

43. **Develop Models** Draw a cladogram that is supported by the data.

44. **Evaluate Models** What aspects of the cladogram are strongly supported by the data? Which are more weakly supported? Explain your evaluation.

LANGUAGE ARTS CONNECTION

Write About Science

CCSS.ELA-LITERACY.WHST.9-10.1, CCSS.ELA-LITERACY.WHST.9-10.2

45. **Write Explanatory Texts** Write a paragraph to explain how species are classified into clades.

46. **Write Arguments** How is the clade system of classification more useful than the Linnaean taxonomic system?

Read About Science

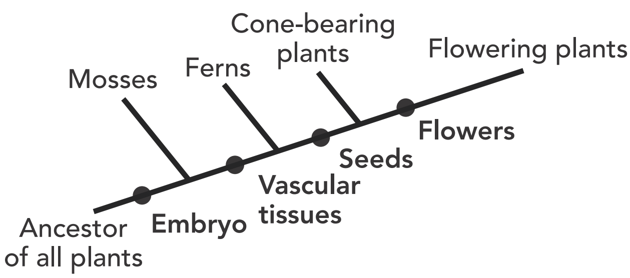
CCSS.ELA-LITERACY.RST.9-10.1

47. **Key Ideas and Details** You are a reviewer of a paper on the discovery of new species in the Amazon jungle. Two new species of beetles have been found, beetle A and beetle B, that closely resemble each other but have somewhat different markings on their wings. In addition, both beetles resemble beetle C, a species that has already been identified. How could DNA similarities be used to help determine whether beetle A and beetle B are more closely related to each other or to beetle C? Cite evidence from the text to support your analysis.

CHAPTER 19

END-OF-COURSE TEST PRACTICE

Questions 1–3 refer to the following diagram.



1. According to the cladogram, which of these organisms appeared before all the others?
A. mosses
B. a plant with vascular tissue
C. an organism that developed from an embryo
D. a plant that made seeds
E. ferns

2. What conclusion about flowers is supported by the evidence in the cladogram?
A. Flowers evolved more recently than seeds and vascular tissue.
B. Flowering plants have a reproductive advantage over cone-bearing plants
C. Most plants alive today produce flowers.
D. Flowers are a trait of living plant species, but not extinct species.
E. Flowers evolved from cone-bearing plants.

3. Two students are studying plants to determine the closest relatives to cone-bearing plants. Which conclusion could they make based on the cladogram?
A. Cone-bearing plants are most closely related to ferns because they both have vascular tissues.
B. Cone-bearing plants are most closely related to ferns because they share the most recent common ancestor.
C. Cone-bearing plants are equally related to mosses, ferns, and flowering plants because they are all in the same clade.
D. Cone-bearing plants are most closely related to flowering plants because they both have flowers.
E. Cone-bearing plants are most closely related to flowering plants because they share the most recent common ancestor.

4. Compared to the Linnaean system of classification, what is the advantage of classifying species into clades?
A. Clades show evolutionary relationships.
B. Clades identify domains and kingdoms.
C. Clades group single-celled organisms separately from multicellular organisms.
D. Clades include more species.
E. Clades exclude species that are now extinct

5. Scientists struggled with classifying red pandas and giant pandas because they have physical similarities to both raccoons and bears. How has the availability of DNA evidence affected the evolutionary classification of organisms such as the pandas?
A. Organisms with the most shared derived genetic characters are considered the most closely related.
B. Organisms with the most shared derived genetic characters are classified in the most clades.
C. DNA evidence has had little impact because derived physical characters are still more important than derived genetic characters.
D. Derived genetic characters can be used to identify evolutionary relationships, but only if organisms have some shared physical characteristics.
E. DNA analysis has confirmed species classifications based on derived physical characters, but no new classifications have been suggested.

ASSESSMENT

For additional assessment practice, Go Online to access your digital course.

If You Have Trouble With...					
Question	1	2	3	4	5
See Lesson	19.2	19.2	19.2	19.2	19.2
Performance Expectation	HS-LS4-1	HS-LS4-1	HS-LS4-1	HS-LS4-1	HS-LS4-1